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ITS USE AND APPLICATION

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IRRIGATION WATER
ITS USE AND APPLICATION

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Irrigation is usually profitable in the areas of the Prairie Provinces where rainfall is insufficient. This publication explains why and when different soils require irrigation water and how to apply it by gravity or sprinklers. Also, it describes the variations of these methods and their characteristics.

WATER AND SOIL

Only a limited amount of the water that a soil can hold is useful to plants. Spaces or pores between soil particles make up about half the volume of a soil. These are large and small. Air and water can occupy them, but since roots need air, all the pores should not be full of water. The large pores allow water to move downward by gravity but small pores hold it by capillary tension. This capillary water is the most important for plant use.

FIELD CAPACITY, PERMANENT WILTING POINT AND AVAILABLE WATER

Water fills all the pores in a soil for a short time after a heavy rainfall or an adequate irrigation. In a day or two the water in the larger pores drains away by gravity. The smaller pores hold the remaining water by a tension that is slightly more than the force of gravity. The soil is now at field capacity.

Some water evaporates from the soil surface. Plants use much of what remains. After a time it is difficult for plants to remove water. The less there is of it the more tightly soil particles hold water in strong, thin films. Eventually, the plants cannot take up water from the soil as fast as they give it off. Then the plants wilt. If wilted plants do not recover when surrounded by air that is saturated with moisture, the soil is at the permanent wilting point.

Available water is the difference between field capacity and permanent wilting point.

Field capacity, permanent wilting point and available water of a few soils of southern Alberta are:

	Field capacity %	Permanent wilting point %	Available water %	Available water in./ft.
Coaldale clay	33	19	14	2.5
Lethbridge silt loam	22	10	12	2.0
Chin loam	21	10	11	2.0
Cavendish loamy sand	13	5	8	1.4

These quantities differ because particle sizes of soils vary. Sand particles are much larger than clay particles and sandy soils have a great proportion of large pores through which water can move by gravity. This is why sandy soils hold less water and you have to irrigate them more often than clay soils.

MEASURING SOIL WATER CONTENT AND AVAILABILITY

Soil water content is measured by oven drying and weighing. A sample of about 50 grams (almost a tenth of a pound) is weighed, dried overnight in an oven at 105°C, and reweighed. The percentage of water on an oven-dry basis is then calculated as follows:

$$\text{Water \%} = \frac{\text{wt. of wet soil} - \text{wt. of dry soil}}{\text{wt. of dry soil}} \times 100$$

Oven-dry weights are necessary for accurate work because a soil can readily lose water to or absorb water from the surrounding air.

Water is held in the small pores by capillary tension. In the soil this tension is known as matric suction. At field capacity the matric suction is about 1/3 atmosphere and at the permanent wilting point about 15 atmospheres. Do not be confused by the terms tension, suction, or pressure. All three refer to a force and can be measured by a common unit, the atmosphere. An atmosphere is the weight of air at the earth's surface at sea level and is equal to the pressure exerted by a 33.9-foot column of water. In other words, our atmosphere can suck water almost 34 feet. This is the reason lift pumps must have their cylinders within this distance of the water surface.

A tensiometer is used for measuring matric suction. It consists of a porous ceramic cup connected by a tube to a mercury manometer or pressure gauge. It is the only instrument that gives a direct reading of water availability. However, its useful range is less than one atmosphere, it requires frequent servicing, and it can be damaged by frost.

There are other instruments that measure water availability and water content indirectly. One measures the electrical resistance between electrodes embedded in plaster of paris, plastic, or fiberglass blocks buried in the soil. Such a block reaches equilibrium slowly, but it is useful over a larger range of soil water than the tensiometer.

The neutron probe is another instrument. It consists of a radioactive source that scatters fast neutrons that collide with hydrogen atoms and return as slow neutrons that can be counted. It is very accurate and covers the entire water range.

These instruments are relatively expensive and require care and maintenance. Some require a specially trained operator. For these reasons they are not likely to become widely accepted for some time.

WHEN TO IRRIGATE

Here is how you can estimate soil water content:

- With a shovel or auger obtain a soil sample at a depth of 6 to 18 inches depending on the crop and stage of growth.
- Take a handful of soil and form a ball with gentle hand pressure.
- Toss the ball up about a foot and allow it to drop on the palm.
- If the ball does not crumble within 5 tosses the soil contains more than half of the available water and you do not need to irrigate.
- If you can form a ball but it crumbles on tossing, only 1/4 to 1/2 of the available water is left in the soil. It is time to irrigate.
- If you cannot form a ball, the soil contains less than 1/4 of the available water and is too dry.

For best yields of most crops make sure that the soil contains more than half of the available water.

In southern Alberta the Provincial Department of Agriculture, through the Irrigation Gauge Program, helps you to determine when to irrigate. This method, based on a correlation of weather factors and plant growth, was modified at the Lethbridge Research Station for the area. It takes into account the kind of crop, stage of development and growing conditions such as temperature and rainfall. You may follow the resulting irrigation recommendation exactly or modify it to suit the moisture condition of a specific field.

SOIL TYPES

Sandy soils hold from 0.5 to 1.0 inch of water per foot of soil. Loam soils hold 1.0 to 1.8 inches and clay soils 1.4 to 2.5 inches. The maximum root zone for most crops is 4 feet. Therefore, the amount of water held in the root zone varies from 2 to 10 inches depending on the soil type.

For example, Chin loam at field capacity (22 percent water) holds 3.8 inches of water per foot, 2.0 inches of which is available for plant use, and 1.8 inches is not. Soil containing half the available water holds 2.8 inches. To bring this soil to field capacity you have to apply an additional 1.0 inch per foot or 4 inches per 4 feet. You may be able to do this with a sprinkler system or an efficient gravity method. Farm irrigation efficiency varies from 30 to 80 percent because of water losses by evaporation, waste at the ends of fields and deep percolation from over-irrigation. At an average irrigation efficiency of 60 percent, you have to provide 40 percent more or a total of 5.6 inches of water per irrigation for 4 feet of Chin loam. You apply less water per irrigation to a lighter soil (sand) and more to a heavier soil (clay).

SOIL SALTS

All soils contain salts. Some salts dissolve in water and either surface water or groundwater transports them readily. In humid regions groundwater washes away excess salts into streams and eventually to the oceans. Where rainfall is low and evaporation high the salts tend to accumulate in the soil. Excess salts affect germination of seeds and plant growth.

Salted soils are classified by the kinds and amounts of salts found in them. Those that have sufficient amounts of soluble salts to interfere with normal crop growth are called saline soils. Alkali or sodic soils have an excess of sodium salts and are much more difficult to reclaim. Solonetz or 'blowout' soils are an example of sodic soils. The terms white and black alkali are inaccurate and are no longer used.

Before you can reclaim saline soils you must provide adequate drainage. Then you can flush out the salts with an excess of water. You may have to use gypsum or some other ameliorant on sodic soils before you can wash the salts away. The amount of salt, soil permeability and the cost to drain will determine if it is economical to reclaim the soil.

If you irrigate too much you may raise the water table (level of groundwater) and cause saline soils. This happens when water accumulates in the soil faster than it can drain away. Later, the water may evaporate, recede or be used by plants, but some of the salts will remain in the root zone.

Salt problems may arise from canal seepage. Lining the canal with a waterproof material such as plastic or concrete will prevent this. Tile drains or open ditches intercept seepage from canals.

If reclamation is not feasible:

- Apply barnyard manure and plow under green manure crops.
- Sow crops when soil moisture is best for germination.
- Sprinkle frequently but lightly with water while the crop emerges.
- Grow salt-tolerant crops such as tall wheatgrass, barley, sugar beets, bird's-foot trefoil, rape and slender wheatgrass. Alfalfa and sweet clover are moderately tolerant.

CONSUMPTIVE USE

Consumptive use is the total water a crop uses in a season to build plant tissue and in transpiration plus the water that evaporates from the soil surface and from the leaves and stems of the plants. It does not include water that drains down through the soil beyond the reach of plant roots.

The length of the growing season is the most important of many factors that affect consumptive use. Alfalfa and sugar beets are long-season crops and may require twice as much water as a short-season crop like peas. Consumptive use is greater in dry, hot periods than in wet, cool periods.

Daily water use depends upon the stage of crop growth and may be related to the extent that the plants form a ground cover. Tiny seedlings require little water. As they grow they require more water daily up to the stage of maximum growth. When plants are mature and harvest approaches they may require less water. Cereals that ripen in the field require less water at harvest than canning peas or hay that you harvest at their most vigorous stage of growth. Individual crops under similar conditions may vary in their need for water and in their ability to extract it from the soil, particularly as the soil becomes drier.

Consumptive use of water for a number of crops commonly grown in southern Alberta is recorded in the table. These figures are for crops grown under good irrigation and fertility management. They vary from year to year. Daily

Consumptive Use and Average Daily Use of Water for a Number of Crops Grown in Southern Alberta

Crop	Average consumptive use in.	Average daily use in.
Alfalfa	26	0.16
Grass (pasture)	24	0.16
Sugar beets	22	0.14
Potatoes	20	0.15
Soft wheat	19	0.19
Hard wheat	18	0.18
Oats	16	0.17
Barley	16	0.18
Flax	15	0.16
Field corn	15	0.14
Canning corn	15	0.12
Tomatoes	14	0.14
Canning peas	13	0.17

water use figures in the table are averages for the whole growing season. The actual rates of daily use are lower in the spring and perhaps twice as high in midsummer than those shown.

Some of the water comes as rain. You must irrigate to supply the remainder. Since soils have limited storage capacity, irrigate at intervals.

METHODS OF APPLYING WATER

Gravity and sprinklers are the two primary methods used to apply water. Since crops respond equally well to water applied by either method, other considerations influence the choice. Gravity methods are more common than

sprinkler methods because:

- Capital expenditures are usually lower.
- Operating costs are lower because there is no pumping.
- Weather conditions, particularly wind, are not detrimental.
- You may irrigate more acres per day if you prepare the land suitably and have an adequate supply of water.

Some situations may favor sprinkler irrigation:

- Rough land, that is expensive to level, subject to erosion and difficult, if not impossible, to irrigate uniformly by gravity methods.
- Very sandy soils that require frequent light irrigations and on which there is a limit to the length of furrows.
- Lack of skilled labor to irrigate by gravity.
- The need to "irrigate up" or supply moisture for germination purposes. With a sprinkler system it is much easier to distribute the water and to control the rate.
- Limited water supply. Sprinkler methods are more efficient than surface methods and irrigate a larger acreage with a given supply of water.

You may combine sprinkler and gravity systems and use the sprinkler for specialized operations such as "irrigating up", irrigating non-leveled areas, or supplying a light irrigation immediately before harvesting sugar beets or peas. There are advantages to such an arrangement, but usually a farmer does not use either system with maximum efficiency.

Within each primary irrigation method there are many specific methods or types of equipment. Each has particular advantages under certain circumstances. Various provincial extension services will help you to choose the method and the variation that is best for your conditions.

IRRIGATING BY GRAVITY

Field Ditches

Field ditches are usually temporary ones that you place in the field each year and supply from a permanent head ditch. You may run them parallel downfield (border ditches) or follow the contour of the land (contour ditches). In practice you open the ditch bank at intervals and permit the water to spread over the area between the ditches. For close-seeded crops such as cereals and pastures use either border or contour ditches. Use contour ditches when field surfaces are too irregular for border ditches and land leveling is too costly. Border ditches require a more uniform slope. A more efficient irrigation is possible with this method than with contour ditches.

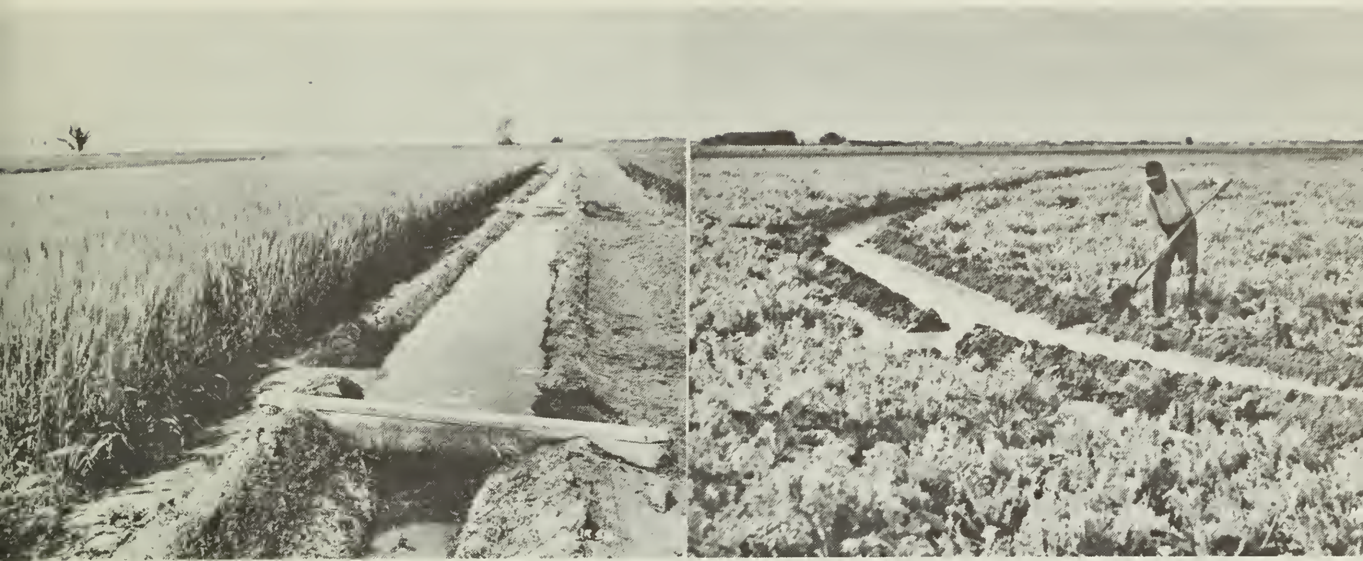

Figure 1 — Ditch irrigation. The field on the left contains border ditches. The contour ditch method on the right requires little land preparation, but labor requirements are high and irrigation efficiency is low.

Some disadvantages of field ditches are:

- Ditches may occupy much of the field.
- Efficiency is low because it is difficult to irrigate uniformly.
- Soil erosion is a hazard on steep slopes.
- Labor requirements are high.

It is often false economy to retain contour ditches where you can employ more efficient methods. The extra labor costs and poor water distribution more than offset the advantages of low investment.

Border Dikes

Border dikes are low ridges running parallel downfield to form boundaries to hold the water. Dikes provide a good way to irrigate fields of pasture, hay and small grains. Usually it is necessary to make extensive land preparation to provide a level field between borders and a reasonably uniform downfield slope. The following advantages justify the investment:

- You may use large heads of water.
- You may apply water uniformly and more efficiently than with contour ditches.
- There is a saving of labor.
- Dikes are low enough to permit implements to cross them.
- The ditches occupy little land and create only a minor weed problem.

Basins

In limited areas the land surface is naturally flat enough to permit construction of field basins (level fields surrounded by retaining dikes). With basins you may have large heads of water, good control and low labor requirements. Since you may arrange them so that excess water from one flows into the next, efficiency is usually high. This variation is primarily suited to close-seeded crops.

Furrows

Use furrows for irrigating intertilled crops, primarily. Normally, run furrows down-slope but place them on the contour on steep slopes to avoid erosion. Prepare the land to ensure continuous and relatively uniform down-field slopes. Spacing of furrows depends upon soil type, the crop and its stage of development. Slope, soil type or a combination of both determines the allowable length of run. Water flows into the furrows from a head ditch through siphons, spiles or sub-laterals. It gradually wets the soil between them. In a properly designed system the soil becomes moist between the furrows in the time it takes to penetrate to the roots.

Corrugations are a variation of the furrow method. They are shallow, narrow-spaced furrows that help to spread water evenly. You can use them with any of the gravity methods especially for close-seeded crops in much the same way as furrows for row crops. Although you normally run them down-slope, you may place them partially on the contour to avoid steep runs. Use

Figure 2 — Furrow irrigation suits row crops. Siphon tubes provide a more accurate and better controlled method of introducing water into furrows than breaking the ditch bank.

only small streams of water in each corrugation and take care to avoid erosion. The length and spacing depend upon soil texture and field slope. Corrugations can greatly improve distribution and reduce labor. You may form them by a special machine or by a cultivator equipped with furrow-opening shovels.

Gated Pipes

You may replace the head ditches required to supply water for most methods of surface irrigation with gated pipe made of metal, fabric or other materials. This is particularly desirable if the field lies above the source of water supply. Gated pipes replace siphons or spiles and eliminate the maintenance of head ditches and seepage from them. Adjustable gates provide a positive control of the distribition of water to furrows. This saves much labor and improves the uniformity of water applications.

Preparing the Land

You may justify few investments on an irrigated farm more than leveling the land to facilitate water distribution. Land-leveling creates field surfaces of a uniform slope. Improvements to head ditches and structures permit the control of water necessary to obtain the total benefits of preparing the land. These benefits include:

- A uniform irrigation that increases crop yields.
- A saving of water because there is less waste.
- The opportunity to irrigate more acres per day with the larger heads of water.
- A reduction of labor and improved working conditions.
- Control or elimination of drainage problem areas.
- Increased land values.

Land development may help you to irrigate 20 acres per day more effectively than you did 5 acres per day before leveling.

IRRIGATING WITH SPRINKLERS

When you irrigate with sprinklers you have high capital costs, high operating costs and the disagreeable chore of moving pipe. The first two problems are very difficult to solve but manufacturers have been vigorously working at the third. A wide variety of sprinkler systems is available to help reduce or eliminate labor. You may use three approaches, either singly or in combination:

- Provide enough equipment to cover the entire field.
- Move the equipment mechanically.
- Use high pressure to throw the water.

In the first approach you can completely automate the system but the

Figure 3 – Considerable land leveling was required to prepare these fields for border dike irrigation. On the right is an adequate, uniform irrigation achieved with a minimum of labor.

capital cost is prohibitive under the present agricultural economy in areas such as southern Alberta. However, there are solid set systems in many urban lawns. In the second, you mount pipelines and sprinklers on wheels, skids, or a self-propelled undercarriage. In the third, you use high pressure to force water over a wide area around each sprinkler, thereby eliminating some of the equipment and the labor required to move it.

Hand-move Systems

Hand-move sytems have sprinkler heads that deliver about 10 gallons per minute (gpm) at about 40 pounds per square inch (psi) pressure, mounted at intervals of 40 feet on laterals. You can move the laterals by hand a distance of either 40 or 60 feet. The initial and operating costs of a hand-move sprinkler system are the lowest. This system applies water uniformly. A disadvantage is that you need hand labor to move the laterals in the field. You may eliminate some of this labor by replacing the many small sprinkler heads with one or more large sprinklers operated at a high pressure (80 to 100 psi). With identical pumping capacity this system will now irrigate about the same area per set but the labor is less because you do not require so much pipe. There are several disadvantages. Pumping costs rise because of higher pressures. Uniformity of water distribution is satisfactory under relatively calm conditions, but not when there is even a light wind. If the high-volume, high-pressure sprinkler spreads water over a rather small area, the soil may not be able to absorb the water at this rate of application.

Mechanical-move Systems

The water distribution, wind effect, and pumping costs of these systems are almost the same as those previously mentioned. They differ only in method of moving.

You may place a conventional hand-move system on wheels or skids and tow it with a tractor. Alternatively you may mount it on wheels and move laterally by auxiliary power or make it fully self-propelled by mounting the lateral on wheels and pivoting it about one end.

It is possible to mechanize a high-volume, high-pressure sprinkler by mounting it on a trailer or on a self-propelled undercarriage.

The rotating-boom sprinkler combines the labor-saving advantages of the trailer-mounted, high-volume, high-pressure sprinklers with a water distribution pattern under windy conditions which approaches that of the conventional sprinkler. This is possible because the rotating booms carry the water over much of the wetted area before they release it from the nozzles. Capital costs and power requirements are high.

Points to Remember

The following points are important:

- A sprinkler system does a good job if the designer considers specific crops, soil types and climate and the operator uses it according to the design.
- No system does a good job under windy conditions, but some systems and some sprinkler heads perform better than others.

Figure 4 – On the left is a typical hand-move sprinkler line system. On the right is a partly mechanized wheel-move system.

- The best way to compare sprinkler system sizes is by pumping capacity.
- No system performs satisfactorily if you operate it at less than its recommended pressure.
- Few systems are flexible enough to accommodate major undesigned changes in nozzle sizes or number of sprinklers.
- Allow some leeway in the design of a system for downtime due to repairs, power failure, or excessive winds.
- Laborsaving adaptations contribute little to quality of irrigation.
- The more mechanized the system the greater is the cost.

You must decide how much additional capital and operating cost you can justify by the reduction in labor and increased convenience of operation.

USEFUL MEASURES AND EQUIVALENTS

One cubic foot per second (cfs) (second foot) equals approximately:

373 imperial gallons per minute
449 U.S. gallons per minute

This quantity of water will cover one acre one inch deep in one hour or one foot deep in 12 hours. It will supply:

75 furrows at 5 gpm per furrow
37 furrows at 10 gpm per furrow
25 furrows at 15 gpm per furrow

1 pound per square inch (psi) = 2.31 feet of head.

You may calculate pump power requirements from this formula:

$$\text{Brake horsepower} = \frac{\text{Gallons per minute (U.S.)} \times \text{head in feet}}{3{,}960 \times .75 \text{ (pump efficiency)}}$$

This gives the required horsepower for an electric motor. For air-cooled engines double the figure. Rate water-cooled engines about 50 percent higher for continuous operation.

A continuous pumping rate of 7 gallons per minute per acre provides for peak crop water use.

A dugout 65 feet × 165 feet and 10 feet deep holds about 1 acre foot of water.

CONVERSION FACTORS FOR METRIC SYSTEM

Imperial units	Approximate conversion factor	Results in:	
LINEAR			
inch	x 25	**millimetre**	**(mm)**
foot	x 30	**centimetre**	**(cm)**
yard	x 0.9	**metre**	**(m)**
mile	x 1.6	**kilometre**	**(km)**
AREA			
square inch	x 6.5	**square centimetre**	**(cm^2)**
square foot	x 0.09	**square metre**	**(m^2)**
acre	x 0.40	**hectare**	**(ha)**
VOLUME			
cubic inch	x 16	**cubic centimetre**	**(cm^3)**
cubic foot	x 28	**cubic decimetre**	**(dm^3)**
cubic yard	x 0.8	**cubic metre**	**(m^3)**
fluid ounce	x 28	**millilitre**	**(mℓ)**
pint	x 0.57	**litre**	**(ℓ)**
quart	x 1.1	**litre**	**(ℓ)**
gallon	x 4.5	**litre**	**(ℓ)**
bushel	x 0.36	**hectolitre**	**(hℓ)**
WEIGHT			
ounce	x 28	**gram**	**(g)**
pound	x 0.45	**kilogram**	**(kg)**
short ton (2000 lb)	x 0.9	**tonne**	**(t)**
TEMPERATURE			
degree fahrenheit	°F-32 x 0.56 (or °F-32 x 5/9)	**degree Celsius**	**(°C)**
PRESSURE			
pounds per square inch	x 6.9	**kilopascal**	**(kPa)**
POWER			
horsepower	x 746	**watt**	**(W)**
	x 0.75	**kilowatt**	**(kW)**
SPEED			
feet per second	x 0.30	**metres per second**	**(m/s)**
miles per hour	x 1.6	**kilometres per hour**	**(km/h)**
AGRICULTURE			
bushels per acre	x 0.90	**hectolitres per hectare**	**(hℓ/ha)**
gallons per acre	x 11.23	**litres per hectare**	**(ℓ/ha)**
quarts per acre	x 2.8	**litres per hectare**	**(ℓ/ha)**
pints per acre	x 1.4	**litres per hectare**	**(ℓ/ha)**
fluid ounces per acre	x 70	**millilitres per hectare**	**(mℓ/ha)**
tons per acre	x 2.24	**tonnes per hectare**	**(t/ha)**
pounds per acre	x 1.12	**kilograms per hectare**	**(kg/ha)**
ounces per acre	x 70	**grams per hectare**	**(g/ha)**
plants per acre	x 2.47	**plants per hectare**	**(plants/ha)**

Examples: 2 miles x 1.6 = 32 km; 15 bu/ac x 0.90 = 13.5 hℓ/ha

INFORMATION
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